

1006
J45

JENS

The Feasibility of Electrical
Equipment on Steam Railroads

Electrical Engineering

B.S

1906

UNIVERSITY OF ILLINOIS
LIBRARY

Class

1906

Book

545

Volume

Je 07-10M



36-4

THE FEASIBILITY OF ELECTRICAL EQUIPMENT ON STEAM RAILROADS

BY
ROY EDWARD JENS

THESIS
For the Degree of Bachelor of Science
in Electrical Engineering

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS

PRESENTED, JUNE, 1906

Part of Roy Jens's 1906 Thesis



Digitized by the Internet Archive
in 2013

<http://archive.org/details/feasibilityofele00jens>

UNIVERSITY OF ILLINOIS

June 1,

1906

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ROY EDWARD JENS

ENTITLED THE FEASIBILITY OF ELECTRICAL EQUIPMENT ON

STEAM RAILROADS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Electrical Engineering

Morgan Brooks

HEAD OF DEPARTMENT OF Electrical Engineering

1906
745

TABLE OF CONTENTS.

	Page.
Statement of Question-----	1
Advantages of Electric Traction	
For Underground, Elevated, Suburban, Branch Lines, and Light Traffic-----	2-3
Comparison of Locomotives	
Power Development-----	3-4
Endurance, Age, Speed, Care-----	5
Comparison of Systems-----	5-6-7
Economic Problem-----	8
D. C. System with Disadvantages-----	10-12
Description of Various Traction Systems Experimented with-	12-14
" " A.C. Single Phase Motor-----	14-16
Financial Comparison of A.C. & D.C. System-----	18-23
Comparison of Limitations of two Systems-----	24-27
Single Phase System on N.Y. N.H. & H. R.R. and Developments Abroad-----	28-29
Conclusion-----	30
Appendices	
Curves and Diagrams of G.E. and Westinghouse Single-Phase traction System.-----	31
Statistics in Steam Locomotives and Portable Sub-stations-	32
Table-Single Phase System-Gas Engine Plant, Frt. Handling,	32-33



PART I.
STEAM & ELECTRIC TRACTION.

At this stage of engineering progress we find the traction question is one of such prominence as to call forth repeated discussion; and in this discussion there are two points around which all the argument centers:

I. - The advantage of electrical equipment over steam equipment.

II. - The relative merits of D. C. and A. C. systems.

The contest for supremacy between steam and electric locomotives has just begun. The steam locomotive has in recent years been greatly improved. Its engineers have taken advantage of every opportunity, to bring it, within its limitations, to its utmost capacity, and locomotives of great power and improved efficiency are now being put into service. On the other hand the electric locomotives, with comparative limitations of power development in their favor, have enjoyed a rapid growth. The distribution of power to more than one set of drivers, to all in the train if desired, thus equalizing draw-bar strains, and the ease of control in single and multiple units (that is, the operation of any number of power units from one car) are points in which it is undoubtedly superior to its rival. These considerations together with several minor ones, as for example; absence of smoke and dirt, elimination of round-house, etc., make a clear case for the electric locomotive.

While the construction and operation of electric locomotives is still in an experimental stage, their performance during the past few years, under varying conditions of weather, rail, and service has been very encouraging to their followers.

Results have shown that electricity meets the demands of modern railroad service which are beyond the capacity of the steam locomotive. The steam locomotive has proven inadequate to the requirements of underground and elevated roads and for these classes of service has been almost entirely displaced.

The advisability of operating suburban lines by means of electricity is receiving considerable attention. The satisfactory handling of suburban traffic for congested districts requires a system that is rapid, safe, and clean. This would mean an increased terminal capacity for handling trains, little or no switching movements, rapid acceleration of trains, quick and smooth stops, the elimination of all objectionable features that result from stifling heat, smoke, dirt, etc..

Many of the branch lines of our large systems which are being operated with steam locomotives can be equipped with electricity to an advantage. The competition arising from parallel electric lines will force this change at many places in the near future. The costly improvements in steam equipment are not meeting this competition. Present indications point to the impossibility of fully developing the earning power of any road until steam is replaced by electrical equipment. Here the advantage of the flexible operation of single motor cars can readily be appreciated, for example; when a car is switched from a through train at a junction point it can proceed on the branch line without the delay that is almost universally necessary under present conditions of steam traffic. This would be an advantage to the traveling public in that it would save stop-overs, expense, and time that would otherwise be wasted.

Where traffic is light the first cost of installation of power plants, and maintenance of the entire equipment would too great to warrant the change, but the advantage of the electric equipment for handling the traffic would increase the capacity and facilities of the road and it would be this increase in business handled that would justify an increased cost in installation and operation of this system. It is predicted that electrical equipment will afford quicker freight and passenger service, owing to the economy at which small trains can be operated. This would give more frequent service at small towns, which now are compelled to contend with one or two trains a day, and would eliminate delayed freight shipment. This equipment would permit an increased capacity in mail service and greater rapidity in handling freight, and this would be a point in favor of measures frequently presented to Congress advocating heavier parcel service in the mails, and the probable elimination of express companies.

An idle boast of the steam engineer is that the steam locomotive has come and is here to stay. Pride permits them to admit defeat in rare cases. Their strong argument is that they will not be defeated in the heavy tonnage haul of considerable distance. But it has been demonstrated that combined in units it is entirely possible to provide in the shape of an electric locomotive more powerful train movement than is possible in the case of any steam locomotive which can be operated by a single man. It has also been proved by actual practice that for hauling heavy tonnage on severe curves and grades the greater speed can be maintained by the electric locomotive. On curves a smoother and longer tractive effort can be maintained by electric loco-

tives and there is less danger of derailment. On grades the endurance of the steam locomotive is less due to the limited supply of excessive steam. With this increasing demand for steam its cost increases rapidly. Enormous expenditures of capital are made in railway construction in order to escape the inefficiency of operation which would result from operating the steam locomotive on grades heavier than a certain limit.

A new economic theory of railway location presents itself with possible saving of capital investment in the construction of railway, which will very materially reduce the total capital needed, by having given a locomotive whose horse power and cost per horse power hour over the range of speed and tractive effort desired in practice. The electric locomotive employs a voltage control for speeds and as a consequence the total horse power and cost per horse power hour can be maintained constant over the range of tractive effort desired.

It possesses the ability of developing for an hour or so a greatly increased power. This increase of power may be utilized in maintaining high speeds, or it can be applied in pulling heavy loads, or in climbing grades. This last consideration plainly indicates the adequacy of the electric locomotive for pusher service. Again while descending grades this equipment is able to regenerate and appreciable useful energy back to the line. Electricity can also be effectively applied for braking thus eliminating the wear on brake shoes and the severe jerks experienced at times by the present braking system.

The number of electric locomotives necessary to operate a given service is much smaller than that required with steam

power of the same capacity, owing to the very large daily mileage of which the former are capable. An electric locomotive is easily able to maintain a daily mileage of 500 in 18 to 20 hours and at the end of such a run the care demanded is less and the work that this care involves is not so dirty and unpleasant as in the case of steam locomotives. It is found that electric locomotives can be driven faster over the same roadbed because of -

1. - the absence of terrific vibrations, produced in the steam locomotives, by the reciprocating parts,
2. - The absence of severe and injurious pounding of the rail by a probable unbalanced weight on the drivers
3. - The limit of the velocity of steam and piston, though complicate gearing might be a means of overcoming this.

A steam engine could not run 90 miles per hour continuously without breakdown. While it is estimated that an electric locomotive can maintain twice this speed for several consecutive hours, its speed is seriously limited only by the air resistance, the supply of power being unlimited. The construction of the electric machine is such as to permit it to glide along smoothly even at this high rate of speed. One of the noticable results of this feature is the fact that its life is longer than that of its rival, the power station on wheels.

A system of electric traction possesses a very desirable feature in the centralization of power source, this adding greatly to the ability to increase efficiency of power production. In consideration of the limited supply of coal this is worthy of attention. In mountainous countries where permanent and concentrated

supply of cheap power is available, electricity can be economically generated. It is true that an electrical equipped railroad would be preferable to one of steam equipment in mountainous countries due to its superior operating capacity.

There are several minor considerations which contribute to the superiority of electric traction; for example,

- (a) - The elimination of smoke, dirt, cinders, etc., at terminals, (see page 1.)
- (b) - The abandonment of, the dirty round house, and the unpleasant work such as cleaning fires and ash pits, washing out boilers, and firing up and maintaining fires when not in use.
- (c) - The discarding of, turn table, coal tressles, and water supply equipment.
- (d) - The absense of tender in trains, a dead weight of one third that of the locomotive.

The public is constantly observing and a system free from these afflictions is sure to command their patronage.

Electric heating, though more expensive than the system at present in vogue, is an ideal method, and its additional cost is more than off-set by the reduction in cost of lighting an electric train as it is but twelve per cent that of the present system. Besides, this effective system of lighting furnishes at a mere nominal cost the most powerful head light obtainable. The desirability of such a headlight has moved the Chicago & Alton to introduce the system they are now using.

Statistics taken from eighteen different operating roads of each type, show that for electricity the cost of operation

is about 65% of the gross earnings against 75% for steam, and the cost of maintenance about 6.5% against 9.4% for steam. The conditions of operation are not known, but these will serve to give an idea of the present relation of the two systems from a financial stand point.

With the increasing demand for, and probability of greater speed of passenger service comes the plea from the people for protection against the horrible accidents which are constantly occurring on our present railroads. The exalted esteem that the art of electricity has commanded in the people naturally brings the general demand upon work of this nature to provide means for safe operating conditions. Up to date such devices have given only partial satisfaction and better equipment has been looked for. It is now in the nature of high-tension Telephony that a signaling and telephoning system appears to be applicable in the way of telephoning and signaling between electric cars in operation, and cars and stations by merely the installation of a suitable outfit upon or at each of these places. This would enable the engineer and dispatcher to at any time locate a train and thus avoid possibility of collision. As to crossings and switches it is evident that time will develop the present safety devices to afford a greater degree of safety. When high-tension Telephony can be effectively developed and operated its use in electric railroading will decidedly help the progress of the latter. A point decidedly in favor of this progress is that electrical equipment can be so installed as to allow complete safety in operation of steam cars over the same road. This would nourish the cause of gradual electrification of steam railroads.

The economic problem involved, is a determination of where it would pay to install the electrical equipment. This can be done theoretically by formula or graphical solution. Allowing A and A' to be the capital investment required for steam and electricity respectively, Y and Y' the respective maintenance and interest charge, X and X' respective traffic in tons per mile of track, T and T' respective cost of operation per ton mile, R and R' respective rate or fare (in cents per ton mile or passenger mile) then applying the formulae; -

$$\begin{aligned} A/Y + XT &\leq A'/Y' + X'T' \\ XR &\geq X'R' \end{aligned}$$

(by knowing the respective costs of installation and operation, cost of maintenance and interest) the density of traffic, at some rate R', can be figured which would be necessary to warrant this change from steam to electricity.

The graphical method of finding the point where it would pay to install electrical equipment is here shown;-



These curves are plotted for each system, showing the relation between the cost of operation per ton mile and density of traffic. The cost of operating electrically is shown to be high for light traffic but decrease rapidly with increase of traffic, while the cost of steam operation is nearly constant, only de-

creasing slightly with increase of traffic. Where these curves cross will designate the amount of traffic required to warrant electric installation. A point above this could be taken due to the expected increase in traffic on the electric roads. The shape of the curves though different for various kinds of service, will indicate the relative values for the two systems.

In any case, however, before electricity can extensively supersede steam service, we must demonstrate, practically and not theoretically, from actual installation and operation, that the results will be obtained as predicted, for railroad operators will not make heavy expenditures to increase the business and reduce operating expenses unless they are assured of the net results.

The question confronting engineers to-day is, "Can an electrical equipment be produced for traction purposes that would warrant this change for through freight and passenger service as well as suburban traffic?" I am of the opinion that there can be, believing, the alternating current single-phase system to possess features most promising for this purpose, and look forward to see it fulfill all demands nearest to satisfaction.





UNIVERSITY OF ILLINOIS-URBANA



3 0112 086825004